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SUMMATION REPORT

SAND PROPERTIES AT CANADIAN FOUNDRIES

EVALUATION AND MEASUREMENT

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FOREWORD

The 52 foundries visited under this project were selected to represent the broadest possible cross-section of the industry in terms of geography, type of metal cast, casting size and relative sophistication. This group can be considered representative and the observations noted in this report can be construed as generally pertaining to the Canadian foundry industry.

The fact that a foundry does not have good sand control does not imply in any way that its final products are necessarily inferior. What it does imply is that productivity is lower and costs are most likely higher than they need to be. Thus the major thrust of this work is to strengthen the competitive position of the industry to ensure its continued viability.

R.C. Shnay, P.Eng.

ABSTRACT

The CANMET Mobile Foundry Laboratory was established to provide direct on-site technological assistance to Canadian foundries. Robert Shnay and Associates Ltd. was retained to provide technological support in all areas concerned with moulding and coremaking. This report outlines the procedures followed for each foundry visit. The sand testing program is described. This was designed to provide the maximum information within the time and space limitations.

Three distinct groups of tests were identified - control tests, analytical tests and special tests used for specific problems. Where the foundry had a sand test program, duplicate tests were done to provide a check on their procedures.

The sand tests included in the program are listed and described in Appendix A of this report. A basic progressive method of sand control is outlined in Appendix B.

In general even the foundries that had a complete sand test program did not have effective sand control. Some of the shortcomings were due to improper testing methods and inadequate equipment. But there was also a general tendency to merely record data and little attempt to use it for actual process control.

Attitudinal problems included a lack of awareness of the costs of inadequate sand control, an inabiiity to adopt a systematic approach, and a lack of knowledge of the functions and limitations of additives. Management and technical staff obviously lacked the necessary training and appeared to be reluctant to involve themselves with sand control. The tendency to economize by conserving burnt-out sand was a classic example of misguided economics, since the money saved was probably spent many times over in the cleaning room and scrap bin.

The most common operational problems were found to be the use of excessive amounts of binder and other additives. Productivity was decreased significantly by the use of facings, by the need to riddle sand and the time wasted in using sticky or wet material. Inadequate mulling was commonly encountered. There were also several cases where inadequate dust control and sand segregation problems caused difficulties in sand control.

The major conclusion that must be drawn from this program is that there is a great need for education and training in sand control. Foundry managers must also realize the benefits in cost reduction and productivity that are available to them.

EVALUATION AND MEASUREMENT OF SAND PROPERTIES AT CANADIAN FOUNDRIES

1. Introduction

1.1 Objectives and Terms of Reference

The CANMET Mobile Foundry Laboratory was established to provide direct on-site technological assistance to Canadian foundries. A program was initiated in January 1984 to visit 52 Canadian foundries of all types from the Atlantic Provinces to the Lower Mainland area of British Columbia.

The purpose of the project was to examine the production techniques and process control systems used by the foundries and recommend changes that could improve quality, reduce scrap and increase productivity. In some cases the mobile laboratory staff simply provided a useful check to the foundry by comparing test results and/or calibrating test equipment. New technology was demonstrated and specific problems were investigated.

Robert Shnay and Associates Ltd. had the responsibility of designing a sand testing program, supervising the sand testing at each foundry and interpreting the results. This firm provided the technological support in all areas concerned with moulding and coremaking. An additional responsibility was to help the CANMET staff in assessing general foundry practice and in analyzing casting defects.

1.2 Procedure

As a rule each visit was limited to two working days. The usual agenda was as follows:

Day 1 - (a) A preliminary meeting with the foundry management and/or supervision to describe our procedure and gather general information about the foundry - its markets, production methods and any current problems.

(b) A guided tour of the foundry by the entire team to become familiar with the general layout and meet the supervisors and other key people.

(c) The team members then separated to gather the specific data needed for their individual tasks.

(d) The next step was to develop sampling and testing programs which would be of maximum benefit to the foundry and still not exceed the limits of space, facilities and time available for the work. During this period the CANMET technicians prepared the mobile laboratory and its equipment for the tasks to be done.

(e) Sampling, and testing as well as observations of the foundry operations generally continued until noon of the second day.

(f) The author and the CANMET leader consulted on the foundry operations they had observed and usually made a joint examination of typical casting problems.

(g) The early part of the second afternoon was spent interpreting the test results and shop observations.

(h) A meeting was then held with the foundry manager and the supervisors to present a summary of our findings and recommendations.

This meeting and the ensuing discussion completed the field program.

The Mobile Foundry Laboratory was open to visitors throughout the two day visit. Workers, supervisors and managers were invited to visit the facility.

These invitations were generally accepted. Some key people had their first opportunity to see some of the equipment and witness the tests.

Every foundry visit was followed up with a fully-detailed confidential report.

Although each member of the team concentrated on his own individual tasks, there was a high degree of collaboration to ensure that the foundry received the best possible advice; and also to ensure that each member of the team understood and was cognizant of all the findings.

2. The Sand Testing Program

2.1 Design of the Test Program

The "Mold and Core Test Handbook" published by the American Foundrymen's Society lists more then 100 standard or common tests. Some of the tests have broad significance, others apply only to a limited range of conditions. Furthermore some of the tests can be done in minutes using relatively simple equipment, others take several hours or days and may require highly sophisticated equipment. The design of the test program was governed by three major constraints. The first was the availability of space in the mobile laboratory. Secondly, the test conditions had to be compatible with the conditions required for other concurrent test programs. Finally, the test program had to be executed and the results interpreted within a time span of two days.

In view of the above constraints as well as the general objectives of the project, the following design guidelines were developed.

(a) to have the means to examine and analyze the major moulding and coremaking materials and processes that were likely to be encountered;

(b) to have a test program that would yield optimal information in the time available;

(c) to select tests which separately, or in combination can be used to infer other properties at least in a qualitative way;

(d) to select tests which can be readily correlated to casting quality;

(e) to limit the tests and test procedures to those described in the "Mold and Core Test Handbook" published by the American Foundrymen's Society.

Consideration of these guidelines led to the identification of three distinct groups of tests.

(a) control tests which can be readily correlated with the moulding and casting operation - e.g. permeability and compactability;

(b) Analytical tests which can explain or at least be correlated with the control tests - eg. AFS Clay;

(c) Special tests of raw materials or prepared sand which can assist in the solution of specific problems - eg. acid demand value.

A full listing of the sand test program is presented in Appendix A.

2.2 Operation of the Sand Test Program

The tests that were done and the subsequent recommendations had to be adapted to suit each particular situation. If a foundry had no sand control whatsoever, there was little point in giving them a body of highly precise data which they could not use. A foundry with a sand control program benefitted from tests which they did not usually perform as well as checks of their testing procedures and equipment.

As a general rule where a foundry did take regular samples for testing they were asked to take double samples and give half to the mobile laboratory for testing. In the other cases samples were taken independently and the point of sampling was chosen to give the most meaningful results.

Where significant differences were found between the results, the tests were usually repeated. If no error was found, the procedures used by the foundry and their testing equipment were checked.

The sampling and testing program was adjusted for each foundry in an attempt to provide the most useful information within the time available. In most cases the work was concentrated on the moulding systems. Coremaking materials and processes were analyzed only when a particular problem was brought to our attention.

The testing program was coupled with observation of the foundry operations and examination of the castings. This procedure helped in selecting the samples that were taken, the tests that were performed and facilitated the interpretation of the laboratory results.

2.3 Interpretation of Sand Test Data

The sand tests selected for this project are listed in Appendix A with a brief description of the information conveyed by each one. The interpretation of such data is relative to the methods used in each foundry. The type of moulding equipment, the alloys cast and finally the size and configuration of the castings produced are all involved. Basically the sand tests can be used as diagnostic

tools which may point the way to solving a particular problem or they can be used as somewhat indirect indications of the conditions within a sand system. There are no ideal or acceptable test values that can be applied to all foundries. However some test values have been found to generally yield satisfactory results are noted in Appendix A.

A completely detailed treatment of this subject is obviously beyond the scope of this report, and in fact does not exist in any concise and organized form. Each of the 52 foundries which were visited could provide a separate and unique example. This apparent complexity is probably one of the main reasons sand technology and sand control have not been given the attention they deserve.

A basic sand control system has been outlined in Appendix B. This presents a step-by-step approach with some guidelines to interpretation. Such a control system coupled with the description and significance of each test can provide a starting point for any foundry.

3. Discussion

3.1 General observations

Thirty of the foundries visited during this program did no sand testing of any kind. Some sand tests were done in 14 of the foundries, but only 8 had adequate testing programs. Unfortunately even these foundries did not have adequate control.

In some cases tests were not being done correctly. Some of the more common errors were:

(a) not using a standard 2 inch specimen;

(b) letting the sample dry out in an uncovered container before testing;

(c) not standardizing the methylene blue solution;

(d) not adjusting the zero prior to taking a permeability reading.

In most of the foundries the sand testing equipment was poorly maintained, and rarely calibrated. Sand rammers were often installed with inadequate foundations. One foundry was using the wrong compactability scale and several were using scales that had been improperly installed. Permeability testing equipment was often poorly maintained and no longer capable of giving accurate results. In several cases the instruments could no longer be calibrated.

The bomb-type moisture meters (calcium carbide) were found to be inaccurate at moisture levels above 3%. When actual moisture levels reached 5%, this type of instrument usually read about 3.5% to 4.0%. It was also found that the old pendulum-type strength testers were not reliable where test values exceeded about 15 psi. Consequently they are simply not adequate for foundries using modern moulding equipment.

Even in the best of the foundries the sand test data were not being used effectively to control the processes. Critical test values such as compactability could fluctuate wildly without prompting any change in procedure. Sometimes the foundry concentrated on controlling one variable such as moisture or green compressive strength without any regard to the other properties. It was rare to find any serious attempt to relate sand properties to casting defects or cleaning time.

Sand test data simply became part of the foundry archives. Management did not appear to be aware of the opportunities to improve both the quality of their products and the efficiency of their operation.

3.2 Common Problems

3.2.1 Attitudinal

(1) The most general problem seemed to be a lack of awareness of the benefits of sand control. There appeared to be an attitude that as long as the casting could be cleaned up and was not scrap - all was well.

(2) There was a common inability to adopt a systematic and rational approach to sand control.

(3) There was a general lack of knowledge and understanding of the functions and limitations of the various additives. In many cases the foundry operators were not aware of the differences between southern and western bentonite. Additives such as woodflour or

cereal were being used as a matter of tradition or habit without recognizing that they were not needed, and were in fact probably doing more harm that good.

(4) Management and technical staffs were generally reluctant to involve themselves with sand control. Very often it was left to individual moulders or muller operators. These individuals had neither the training nor the background required and often relied on a combination of folklore and magic.

(5) Moulding sand is expensive in Canada and there was a widespread tendency to economize by recycling burnt-out sand from the shakeout and to minimize the additions of new sand. Generally, whatever money that was saved in this way, was probably lost several times over in the cleaning room.

3.2.2 Operational

(1) The most common operational problem can be simply stated as too much additive, too little silica. Excess bond, unnecessary additives and too much volatile material probably accounted for more than

50% of the rejects and perhaps 75% of the excess cleaning time. Typical defects resulting from these causes were rough surfaces, penetration, burn-on, stickers and drops.

(2) Sand with poor flowability or excess compactability often decreased mould production simply because of the extra work the operator was required to do. These problems were usually due to using the wrong binder, too much binder, too much moisture or not enough new sand.

(3) Riddling sand onto a pattern or using a facing are ways to compensate for inadequate sand control but can reduce productivity by as much as 35%.

In one case changes made to the sand system eliminated the need to riddle the sand and led to an immediate increase of 20% in productivity.

(4) Inadequate mulling was found to be quite common. This was often due to badly worn wheels or poorly

adjusted plows. In other cases the muller was simply too small and mulling times were reduced to avoid delaying the moulding lines.

There were also cases where the capacity was more than adequate in all respects but it was not used.

A fairly common situation was encountered where the mulling capacity was marginally adequate but too much work was demanded from it because of excess bentonite or other fines.

In one case the bentonite addition regularly added to each batch was eliminated when our tests showed that it was unnecessary and excessive. There was an immediate improvement in flowability. The permeability increased from 160 to 183. The compactability and moisture dropped from 57 to 42 and 4.0% to 3.6% respectively. Finally there was an immediate increase of 3.0 psi in the green compression strength.

(5) Using the wrong type of bentonite and using spurious or unnecessary additives are common problems which stem from a lack of understanding of the functions and limitations of these materials. Fortunately, the AFS has excellent publications that provide concise and factual data in a useful format.*

(6) Excess dead clay and other inert materials absorb water, provide no strength and decrease permeability. Many of the foundries visited in this program did not take adequate measures to remove such material. In one particular case the AFS Clay (fines) was 13.5%. More than half of this material was dead clay, ash and other inert substances. Permeability was low and almost every known casting defect could be found in the reject bins and on the pallets in the shipping room. The foundry had no dust exhaust system, cleaned the floor and put the sweepings onto the sand return belt and did not add any new sand to the system.

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* "The applications of Additives to Clay-Bonded Sand Systems".
"AFS Guide to Sand Additives".

(7) Inadequate or poorly adjusted dust control systems led to a build-up of fines in many sand systems. In some cases excess pressure or improper location of dust control systems removed active clay from the sand.

(8) Segregation of sand in bins, silos or hoppers and funneling in sand bins were found to be common problems. In one case the sand bin had enough capacity for at least 8 hours production, but hot sand returned to the muller within 20 minutes after the shakeout. Situations such as these can make effective sand control extremely difficult. When the sand temperature exceeds about 120°F it requires excess water and the bentonite bond is disrupted.

4. Conclusions and Recommendations

As a major participant in this project, the author's assessment of its impact on the industry is bound to be subjective. However, there were useful and practical suggestions made at every one of the foundries. In general, these suggestions were well accepted and many have already been implemented.

At the very least, sand testing was demonstrated to those foundries who do no testing. Where a program of sand tests was in place, the foundry obtained useful checks on their methods and assistance in interpreting their test data.

On the other side, this program has illustrated the magnitude of the problem and the challenges faced by CANMET in fulfilling their mandate to assist the foundry industry. The experience gained by the MFL staff will provide a strong foundation for further work in this field.

The major conclusion that must be drawn from this program is that a great need exists for education and training in sand control. There is also a concomittent need to develop simple and rational sand control programs that foundry managers can implement with confidence. Even when these needs are fulfilled, the full benefits will not be attained until foundry managers realize the cost and productivity benefits that can be gained through sand control.

5. Acknowledgement

This summation report is the last phase of the project assigned to Robert Shnay and Associates Ltd. under Contract No. OSQ83-00208. As such, it could be interpreted as a description of the work of one man or one outside agency. This is not the case. The author was assisted by 4 teams of 3 men each drawn from the CANMET staff. Although each person had his own tasks and responsibilities, everyone collaborated and helped each other. If this project has been of value to the participating foundries, it is primarily due to the qualities of dedication and cooperation demonstrated by all the team members.

Not only did the various teams work together efficiently and harmoniously, there was also a universal effort to develop a warm and friendly ambience. This helped overcome some difficult times and trying conditions.

Mr. R.K. Buhr, Head of the Foundry Section acted as one of the team leaders, and also provided the overall leadership for the project. His generous help and guidance is sincerely appreciated.

R.C. Shnay, P.Eng.

APPENDIX

A. Sand Tests Performed in the Mobile Laboratory and Their Significance

A.1 Clay-Bonded Sand

(1) Compactability - measures the response of the prepared moulding sand to compaction, and is an indirect measure of bond dispersion (or temper). Typical values are 40 to 45 for high pressure moulding and 45 to 50 for other methods.

(2) Moisture Content - combined with compactability indicates the amount of active clay available in the system. Increasing moisture at constant compactability indicates a build-up of water absorbing materials. If none of these materials are present, and there is an adequate amount of bentonite, about 2.5% to 3.0% will give good results.

(3) Green Compression Strength - combined with compactability can be used to estimate the amount of active clay that has actually been bonded to the sand grains. Observations of

this test and examination of the broken test specimen can indicate whether or not the sand is "brittle" - i.e. will tend to break or tear when drawing the pattern.

If the sand is relatively plastic the specimen will bulge slightly before failing and longitudinal cracks will form. If the sand is brittle the specimen breaks in an hour glass pattern and there is no bulging of the sides.

Misleadingly high values can be obtained due to very tight packing. This is usually apparent after screen distribution and AFS clay tests have been done. A very broad screen distribution with or without a lot of fines will tend to give a high compression strength, but not necessarily a strong mould.

Common ranges of green compression strength are 18 to 25 psi for high pressure moulding and 12 to 18 psi for other methods.

(4) Permeability - measures the ease which with air and other gasses entrapped in the mould cavity can escape through the mould walls. Although affected by moisture and the degree

of bonding, permeability is mainly a function of particle size distribution and fines. Low permeability can cause gas defects, rough surfaces and misruns. High permeability can lead to metal penetration. Generally speaking, the ideal permeability value decreases with the surface to volume ratio of the casting, and increases with the weight of metal poured and the pouring temperature. Foundries producing small non-ferrous castings may get good results with permeability as low as 50. Small intricate iron castings could require 150.

(5) AFS Clay - measures the proportion of material in the sand system which is less than 25 microns in diameter. This material consists mainly of live clay, dead clay, ash, fine seacoal (in iron foundries) and other additives. As a rough rule-of-thumb, safe values tend to be less than or equal to 1½ times the amount of active clay as determined by the methylene blue test.

(6) Methylene Blue Test - is used to determine the amount of active bentonite that is, or could be bonded, to the sand particles. This test is very useful for control. A test

done on return sand compared to one done on prepared sand can indicate the rate at which the clay is burned out during the operation.

This test can also indicate when excess bentonite is present in the system. Such excess causes casting defects and cleaning problems. The maximum amount of bentonite that can be used depends on the surface area of the sand. As a rule-of-thumb these maxima will vary from about 7% for a #55 sand to about 8% for a #75 sand. Excess bentonite also decreases the flowability of the sand.

(7) Loss on Ignition - measures the amount of combustible and/or volatile material in the sand. Generally speaking this should be as low as possible with due regard to situations such as in iron castings where a certain amount of volatile material is required. An excess absorbs water, increases gas formation and decreases permeability.

(8) Density - is the weight of the standard 2-inch specimen used for the permeability and strength tests. The usual specimen weight in silica sand systems is about 150 to 155 grams. In

olivine systems the specimen weight is usually 180 to 185 grams. Records of specimen weight can be used to monitor the sand system. A reduction in specimen weight indicates a build-up of fines. If silica cores are used with olivine moulds, a reduction in specimen weight indicates a build-up of silica. On the other hand if olivine, chromite or zircon sands are use for core or facings in a silica system, an unwanted build-up would be indicated by an increase in specimen weight.

(9) Mouldability - can be used to monitor changes in the flowability of some sands. This test is mainly used for sticky and unstable sands.

A.2 Unbonded Sand

(a) washed and dried green sand

(b) new sand

(c) reclaimed sand.

(1) Screen Distribution - is done to determine the particle size distribution by weight.

In the case of green sand systems, the screen tests provide indications of the degree of the degradation of the sand, the build-up of fines (particles passing through the 200 screen), the packing characteristics and the maximum amount of bentonite that can be used to coat the sand grains.

In the case of reclaimed sand, the screen test is necessary to ensure that bonding and packing characteristics are maintained.

(2) Acid Demand Value - is used to determine the suitability of a sand for use in air-set systems. Sands with high acid demand values should be avoided in acid-cured or acid-catalyzed air-set systems.

(3) Grain Shape - Sands are characterized by particle shape as angular, sub-angular or round. The surface area of the sand depends on the size and shape of the particles. The packing characteristics depend on the size distribution and particle shape. Angular sands have greater surface area to coat with binder, but also offer higher permeability due to more open

packing. The shape is determined qualitatively by examining a washed and dried sample under a low-power binocular microscope.

A.3 Chemically Bonded Sand

(1) Tensile Strength - tests are done on all chemically bonded sands whether used for cores or moulds. In systems such as shell and "Isocure" where complete hardening is achieved in seconds, one set of tests is usually done. In time-dependent systems such as the phenolic urethanes or furans, test bars are broken over a period of time. The results are used to prepare a time vs. strength curve. The results of these tests can be used to monitor the mixing process and establish the amounts of binder and catalyst suitable for the foundry operation.

(2) Loss on Ignition Test - is the same as that used for clay-bonded systems. It can be used to verify the amount of binder in a precoated shell sand and also monitor the

efficiency of a reclamation system by determining the amount of residual binder. In the latter case 2% is usually considered a maximum allowable level.

(3) Other Tests - most chemical systems are adversely affected by moisture, clay or organic materials in the sand. Thus AFS clay, moisture and L.O.I. tests were done when there was an apparent problem.

B. Basic Sand Control

B.1 Green Sand Systems

The following describes a basic green sand control system. It starts at a first level for the foundries which have no control of any kind and progresses through to a fifth level which could provide adequate control for any large or sophisticated operation. A foundry can adopt this program at whatever level is appropriate, or use this program to assess their existing procedures.

(1) Level 1

(a) Compactability Test - This should be done on every batch of prepared sand or at least every 15 minutes if a continuous muller is used. A high level of compactability can be lowered by mulling longer, or reducing the moisture content. A low compactability can be raised by adding water (0.1% will increase compactability by 3 points). Most foundries obtain best results with compactabilities between 40 and 50. The lower part of the range is more suitable for high pressure moulding machines.

(2) Level 2

(a) Compactability

(b) Moisture - at least one moisture test should be done for every 5 compactability tests. The test results should be recorded. If increasing amounts of water are required to maintain the desired compactability, it indicates either a build up of water-absorbing materials such as active or dead clay, and other fines, or that there is not enough new sand in the system. If decreasing amounts of water are required, it indicates inadequate clay bond or too much new sand.

(3) Level 3

(a) Compactability

(b) Moisture

(c) Green Compression Strength

(d) Permeability

The first three of these tests can be combined to estimate the percentage of effective bond, the available bond and the efficiency of the mulling process.*

The permeability test can indicate changes in the screen distribution of the sand and/or a build-up of fines.

Tests (3) and (4) should be performed at least once each time the sand is completely cycled.

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* The calculations are based on equations and graphs published in the AFS Transactions and copyrighted by International Minerals and Chemicals Corp.

(4) Level 4

(a) Moisture

(b) Compactability

(c) Green Compression Strength

(d) Permeability

(e) Methylene Blue (Active Clay)

(f) AFS Clay

(g) Sand Temperature (only if hot sand is a problem)

Sand temperatures below 120°F do not pose any problems. So as long as one can hold the sand in his bare hand there is no need to take readings.

At this stage tests (3) and (4) should be done more frequently - at least twice within the time the sand is cycled or every two hours.

Test (5) - Methylene Blue should be done at least once for every sand cycle. If possible, samples should also be taken from the return sand entering the muller. A comparison of results from return sand and the prepared sand will help to estimate the rate of clay burn-out. Effective or working bond as a percentage of the total active clay will provide a measure of the efficiency of the mulling process.

AFS Clay tests should be done at least once per week. The fines found in this test should be compared to a concurrent methylene blue test to estimate the proportion of fine materials other than active clay.

(5) Level 5

Weekly tests for Loss on Ignition (L.O.I.) and a weekly screen test should be added. The L.O.I. will allow control of combustible and volatile additives. The screen tests will provide a guide in adjusting the new sand additions.

Notes

(1) Each foundry must determine the optimum ranges of test values appropriate to its products and operations.

(2) The frequencies of testing mentioned above are only suggestions and should be adjusted to each situation.

(3) The first control step is achieved by holding the compactability constant. The following levels described above are simply logical extensions of this first step.

B.2 Air-Set Systems

The following steps are required:

(1) Calibration of mixer feed rates for sand, binder and catalyst. This should be done at least once per week depending on activity.

(2) Measure moisture, acid demand, AFS Clay and screen distribution of each shipment of new sand.

(3) Moisture, Loss on Ignition, acid demand and screen distribution should be measured daily on reclaimed sand.

Reclaimed sand should be dry (less than 1% moisture), have less than 2% volatile material and should have a screen distribution similar to that of the new sand.

(4) Tensile strength tests should be done daily or more frequently if the mix is changed. A curve of tensile strength vs time should be developed and recorded. This should be used as a guide to timing the strip and pour operations, or to establish the binder and catalyst requirements which will be appropriate for the production schedule.

For most applications a minimum tensile strength test of 100 psi. should be reached before pouring. This varies with the type of metal and the size and geometry of the casting. Large or complex cores require higher strengths.

B.3 Shell Cores and Moulds

(1) If precoated sands are purchased, each shipment should be checked for tensile strength and permeability.

(2) If the foundry coats its own sand, regular tests should be done to determine cure time, tensile strength, loss on ignition and permeability.